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ABSTRACT

This study was conceived when it was observed that in the laboratory, with few exceptions, college freshmen chemistry students did not know how to make accurate measurements. Once the students were made aware of this, they easily learned how. From this experience and in the interest of breaking the cycle, it was decided to assess the ability of preservice science teachers in a graduate education program to make accurate measurements using common laboratory equipment and to analyze the types of misconceptions they had. Misconceptions are summarized for the preservice teachers' responses on length of a plastic straw and a mass measurement of water placed in a 50mL glass cylinder. (YDS)

Preservice Middle and Secondary School Teachers' Misconceptions about Making Measurements Using Laboratory Instruments

by

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PRESERVICE MIDDLE AND SECONDARY SCHOOL TEACHERS' MISCONCEPTIONS ABOUT MAKING MEASUREMENTS USING LABORATORY INSTRUMENTS

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Though measurement skills continue to be a curriculum focus in schools (American Association for the Advancement of Science, 1993; National Council of Teachers of Mathematics, 1989; National Research Council, 1996), U.S. students score poorly on measurement tests (U.S. Department of Education, 1996, 1997). According to the *Third International Mathematics and Science Study* (TIMSS), U.S. fourth and eighth grade students received their lowest scores in mathematics in areas that assess measurement skills (U.S. Department of Education, 1996, 1997). Measurement scores were not reported for grade twelve (U.S. Department of Education, 1998).

In the TIMSS report, U.S. fourth grade students scored above the international average in both mathematics and science. In science, fourth grade students were outperformed by only one of twenty-six nations and in mathematics by seven of twenty-six nations. Of the six mathematics subtests, only the measurement subtest was below the international average.

U.S. eighth grade students in the TIMSS study scored slightly above the international average of 41 countries in science and scored below the international average in mathematics. The U.S. received its lowest ranking, 36 out of the 41 countries, on the measurement portion of the mathematics assessment. Further results from the study indicate that U.S. eighth graders scored at or about the average in algebra; fractions; and data representation, analysis, and probability. However, they scored below the average in the areas of geometry, proportionality,

and measurement. It was also stated in the TIMSS report that "the weaker performance in these latter three topics may pull the overall U.S. score down to below average" for eighth grade (U.S. Department of Education, 1996, p. 27).

Yet the U.S. literature has consistently reflected the importance of measurement to, both, the fields of mathematics and science. "Measurement has been identified as one of the twelve components of essential mathematics for the twenty-first century by the National Council of Supervisors of Mathematics (1989), which noted that 'students should learn the fundamental concepts of measurement through concrete experiences'" (Geddes, *et al*, 1994).

As a topic of emphasis in the National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards for School Mathematics* (1989), measurement is mentioned as being of "central importance to the curriculum because of its power to help children see that mathematics is useful in everyday life and to help them develop many mathematical concepts and skills" (p. 51). Curriculum standard 10 for grades K-4, states that students should "develop the process of measuring and concepts related to units of measurement; make and use estimates of measurements; make and use measurements in problem and everyday situations" (NCTM, p. 51). Furthermore curriculum standard 13 for grades 5-8, relates that students should "extend their understanding of the process of measurement; estimate, make, and use measurements to describe and compare phenomena; and select appropriate units and tools to measure to the degree of accuracy required in a particular situation" (NCTM, p. 116).

The *National Science Education Standards* (1996) and *Benchmarks for Science Literacy* (1993) suggest that with the advances of modern technology heading into the twenty-first century, accuracy of measurement is becoming increasingly vital. Students must master these skills in order to make informed decisions and for the U.S. to remain competitive in our global

society. Not only is measurement an integral part of the mathematics curriculum, it is also a necessary skill in science.

Hiebert (1984) found that first grade students are ready to learn measurement concepts and benefit from participating in a variety of concrete measuring experiences. He suggests that effective instruction should be designed to deal with children's underlying misconceptions.

Measurement continues to be one of the content strands in the National Assessment of Educational Progress (Reese, Miller, Mazzeo, and Dossey, 1997). According to the National Assessment of Educational Progress reports, the more experience students have using scientific equipment (Mullis and Jenkins, 1988; O'Sullivan, Reese, and Mazzeo, 1997) and the more types of equipment they use (Jones, Mullis, Raizen, Weiss, and Weston, 1992) the higher their achievement level is in science. It would seem to follow that knowing how to use the equipment accurately would also support if not enhance the meaningful learning of science.

Mullen (1985) analyzed how well elementary teachers from a state in the mid-Atlantic region of the country understood measurement by administering a written assessment. The results from the research project indicated that elementary teachers had difficulties with items involving the approximate nature of measurement and operations with approximate numbers (Mullen, 1985). Mullen (1985) also reported that teachers demonstrated many misconceptions about the use of significant digits.

This particular study was conceived when the lead author observed in the laboratory that with few exceptions college freshmen chemistry students did not know how to make accurate measurements. Once the students were made aware of this, they easily learned how. From this experience and in the interest of breaking the cycle, it was decided to assess the ability of

preservice science teachers in a graduate education program to make accurate measurements using common laboratory equipment and to analyze the types of misconception they had.

If our children are to understand the concepts of measurement and be able to accurately perform measurement tasks, then it is imperative that their teachers understand the principles of measurement in order to teach the concepts in an appropriate and accurate manner. If teachers do not understand the fundamental and practical principles of measurement, then it would be highly unlikely that their students will learn these skills from them.

Methodology

As science educators, we were interested in developing a simple performance-based assessment format to evaluate preservice teachers' understanding of measurement. In addition, since the study was conducted as part of preservice science methods courses, we wanted the measurement assessment activities to be easily adaptable to high school and middle school students so that the preservice teachers could use the activities in the future to assess their students' understanding.

For this study, 195 middle and secondary school preservice science teachers (graduate students) completed three different measurement tasks. These tasks involved measuring the length of a plastic straw with a meter stick, the volume of a water sample with a graduated cylinder, and the mass of a test tube stopper with a triple-beam balance. Data were compiled over a three year period for all preservice science education classes offered during that time.

Subjects

The 195 subjects participating in this study had all completed a bachelor's degree and were enrolled in a 5th year teacher-certification program at a major university in the Mid-

Atlantic region of the United States. Indicative of the highly mobile population in the area, over 75% of the preservice teachers had completed their bachelors degree from another institution.

A total of 146 students were enrolled in The Teaching and Learning of Science in Middle Education course. This three credit graduate course is part of the teacher licensure program for preservice teachers grades 4-8. The course emphasizes the collection, organization, and interpretation of data resulting from inquiry-based activities. This is a "hands-on" activities course in the biological, physical, and earth sciences which requires students to plan curriculum materials that meet state and national standards. Field experience in the public schools is also required.

In addition to these students, 49 students were enrolled in Teaching Science in Secondary Schools, which is also a three credit graduate course for preservice science teachers grades 9-12 who seek licensure in earth science, biology, chemistry, or physics. The course involves the methods, materials, content, and organization of science programs. Emphasis is placed on curriculum planning, current methodologies, and trends in education that are applicable to secondary schools. Field experience is required for those seeking initial teacher licensure.

For both classes, 48% of the teachers were between the ages of 20-29. However, the educational level (beyond a bachelor's degree) of students in the two classes varied. For the students in the secondary school class, 26% had earned a master's degree or higher, as opposed to 9% of the middle school teachers. Another difference between the two classes was in the area of gender. The male-female ratio in the middle school class was 24:76, as compared to 52:48 for the secondary school class.

All preservice teachers from both courses completed the measurement tasks during one of the first class meetings in either the Fall 1993, Fall 1994, Spring 1995, Fall 1995, or Spring 1996 academic semesters.

Performance Tasks

Each participant measured (as accurately as the apparatus allowed) the length of a plastic straw using a meter stick, the volume of water in a graduated cylinder, and the mass of a test-tube stopper using a triple-beam balance (Sterling, 1998, 1999). The objects to be measured were all selected or set between the lines of measurement on the measuring devices, thus necessitating estimation of the final digit. The actual measurements for each item were pre- and post-determined by the course instructor and graduate assistant.

Written and oral instructions were presented to the participants in order to ensure that the directions were understood. The two written instructions were, "Make all measurements as accurately as the instrument allows," and "Label all units." In addition, a brief oral explanation of each measurement station was given. Each participant had an unlimited number of attempts to perform the measurement task and could take as many measurements as they deemed necessary in order to ensure that their measurements were accurate. After completing each task, the participants wrote their responses on a data sheet. All measurement data were collected anonymously.

The length measurement station was set up with a meter stick and one plastic straw. The participants were allowed to use any method or procedure that would allow them to measure the length of the straw as accurately as possible using the meter stick. For the volume measurement task, water was placed in a 50 ml, glass, graduated cylinder. A drop of blue food coloring was added in order to allow the meniscus to be read more easily. After all, this was a test of

measurement skills, not vision. In addition, a piece of Parafilm was secured on top of the graduated cylinder to prevent the water sample from evaporating over time. The participants were allowed to move around however they desired in order obtain an accurate reading of the water sample.

In arranging the station for the mass measurement task, two different test tube stoppers and triple-beam balances were set up. Two different mass stations were set up because the preservice teachers generally take much more time to measure mass than either length or volume. To facilitate class discussion of mass data after all measurements were made, the two stations were set up so that the test-tube stoppers had the same mass. This was done by using a more accurate balance and placing a small amount of clay in the hole in the stopper until both stoppers had the same mass on the more accurate balance as the two balances used by the preservice teachers. Each station was labeled separately, and the participants were instructed to record the label on their response sheets. After recording the mass of the stopper, the participants were also instructed to reset the balances back to zero.

Criteria for Accurate Responses

The National Bureau of Standards and National Science Teachers Association (Youden, 1984, 1985) recommend procedures for accurate measurement which are used by scientists and science textbook publishers (Gabel, 1993; Haber-Schaim, *et. al.*, 1987; Nelson and Kemp, 1977). Criteria for determining whether a response was completely accurate, or not, was based on two major factors: 1) accuracy of actual digits measured and 2) designation of the appropriate standard measuring unit.

For recording the actual digits, if a meter stick initially indicates that the length of a plastic straw is somewhere between 19.5 cm and 19.6 cm, then the participant would be expected

to make a more precise reading and determine the most accurate measurement such as 19.57 cm, by estimating the final digit. In addition, a standard error of $\pm$ .02 cm, .2 ml, and .03 g was taken into account when determining the accuracy of the measurements. So in the case of 19.57 cm, the measurements 19.55, 19.56, 19.57, 19.58, and 19.59 cm would be considered accurate.

For the standard units of measurement, the participants were expected to include the appropriate measuring unit in their responses. In the case of length, both millimeters and centimeters were considered correct as long as the appropriate digits and decimal place were recorded. Nonstandard abbreviations of the measurement units were not considered correct.

Analysis of Measurement Misconceptions

The measurement data collected were analyzed for types of misconceptions. For the actual digits measured, the misconception categories identified were (1) number of "significant digits", (2) answers in the form of "fractions", (3) missing "initial digit", (4) "multi-unit" combinations of two or more units in an answer, and (5) one labeled as "other" for measurements that appeared well off the mark. The final number of "significant digits" was divided into three subcategories (all significant figures correct, one significant figure missing, and two significant figures missing). These subcategories were used to record the number of digits that were measured accurately. If the final answer should include four digits and the student gave a correct answer containing only three digits, then the response was recorded in the "one missing figure" category. In another category, participants wrote their responses in the form of fractions, when all of the measuring devices were metric instruments. Missing "initial digit" describes the category that was created for responses where the initial digit was missing such as 9.75 cm, when the correct answer was 19.75 cm. Responses that included two units of measurement in the answer, such as 19 cm 6 mm, would also be marked as incorrect and recorded in the "multi-unit"

category. Finally, a response of 20.8 g to an answer of 27.75 g would be marked as incorrect in the "other" category.

Misconceptions relating to the standard units of measurement existed in two forms: (1) the unit was incorrect, such as a response of 19.77 mm when the correct answer was 19.77 cm and (2) the correct unit was recorded with a non-standard abbreviation, such as "gm" for grams instead of "g".

Results and Discussion

The data were compiled in the form of three different data sets that corresponded to the type of measurement conducted (length, volume, and mass). Each data set was further divided into 2 groups, middle and secondary school preservice teachers. Incorrect answers were analyzed to determine misconceptions.

Accurate Measurements

Though neither group did very well, the secondary school teachers performed better than the middle school teachers on all the measurement tasks (see Figure 1 & Table 1). The chi-square test was used to determine that there is a significant difference between the values recorded for the middle and secondary teachers at the .001 level. Therefore, the null hypothesis stating that there was no significant difference between the ability of preservice middle school and secondary science teachers to make accurate measurements was rejected.

Figure 1. Percentage of completely accurate measurements for preservice teachers on each measurement task.

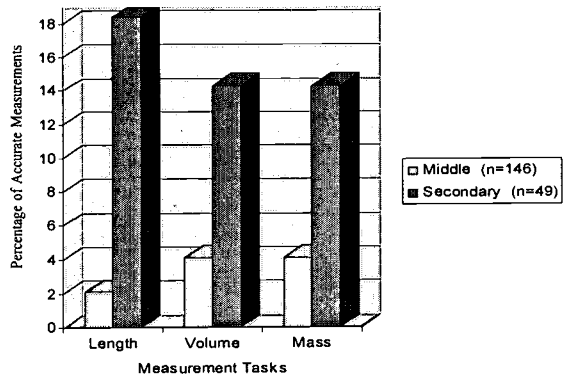

Table 1
Percentage of Completely Accurate Measurements

		Measurement task		
Group	n	Length	Volume	Mass
Middle	146	2.1	4.1	4.1
Secondary	49	18.4	14.3	14.3
Mid. + Sec.	195	6.2	6.7	6.7

Note. $X^2 = 17.1$, df=1, $p<.001$

For the length measurement task, only 6.2% (or 12 out of the total 195 participants) responded with completely accurate measurements for the length of a plastic straw. Out of this group, 9 of the 12 participants who responded correctly were secondary school teachers. When the two groups were analyzed separately, it was found that 18.4% of the secondary school teachers provided correct responses as opposed to only 2.1% of the middle school teachers.

For volume, the data indicated that 6.7% of the teachers provided completely accurate responses for the measurement of a water sample in a graduated cylinder. Again, the secondary school teachers provided more correct responses than the middle school teachers. Of the secondary school teachers, 14.3% responded with completely accurate measurements compared to 4.1% of the middle school teachers.

Results of the mass measurement task indicated that the teachers responded similarly to the way they did on the two other measurement tasks. It was found that 6.7% of the teachers responded with completely accurate measurements for the rubber test tube stoppers. As the two groups were compared to each other, it was discovered that 14.3% of the secondary school teachers provided completely accurate measurements as opposed to 4.1% of the middle school teachers.

Misconceptions in Measurement

For length, the most common misconception for both groups occurred in the estimation of the final significant digit with 74.4% of the preservice teachers making this type of measurement error (see Figure 2 & Table 2). The second most common misconception involved using the wrong standard unit of measurement. The data revealed that 32.8% of the teachers had misconceptions in reporting units of measurement with 40.4% of middle school teachers making more errors in this area as compared to 10.2% of the secondary school teachers. Also for the length measurement task, 7.7% of the teachers had misconceptions that were classified in the fraction category. For missing initial digits, 8.7% of the misconceptions were in this category, 1.0% in the multi-unit category, and 2.1% of the misconceptions were classified in the "other" category.

Figure 2. Percentage of misconceptions on the length measurement task
for middle and secondary teachers.

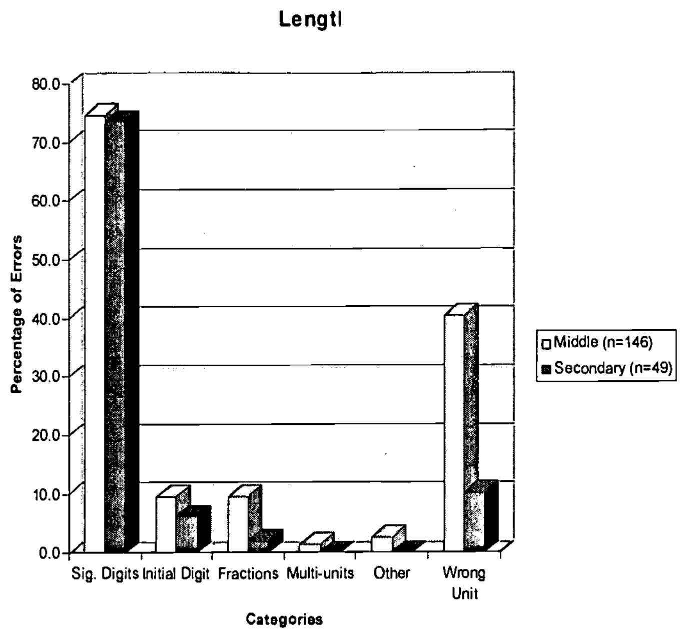

Table 2
Percentage of Misconceptions for Length Measurement Task

		Misconception Categories					
Group	n	Sig. digits	Initial digits	Fractions	Multi-units	Other	Wrong unit
Middle	146	74.6	9.6	9.6	1.4	2.7	40.4
Secondary	49	73.5	6.1	2.0	0.0	0.0	10.2
Mid. + Sec.	195	74.4	8.7	7.7	1.0	2.1	32.8

Note. The values represent percentages of responses due to a particular type of misconception.

For volume the most common misconception was also accurately measuring the significant digits with 83.6% of preservice teachers making this type of error (see Figure 3 and Table 3). Both groups faired well in listing the appropriate unit of measurement for the volume

task, as only 7.2% of them responded incorrectly in this category. This trend was noticed across both teacher groups as only 8.2% of the middle school teachers and 4.1% of the secondary school teachers had misconceptions in using the correct standard measuring unit for volume measurements. The volume measurement task provided fewer misconceptions in the other respective categories. Only 2.1% of the misconceptions were classified in the fraction category, while only 1.5% of the misconceptions fit into the missed initial digit category. There were no misconceptions in the multi-unit category, but 5.6% of the misconceptions were classified in the "other" category.

Figure 3. Percentage of misconceptions for the volume measurement task for middle and secondary teachers.

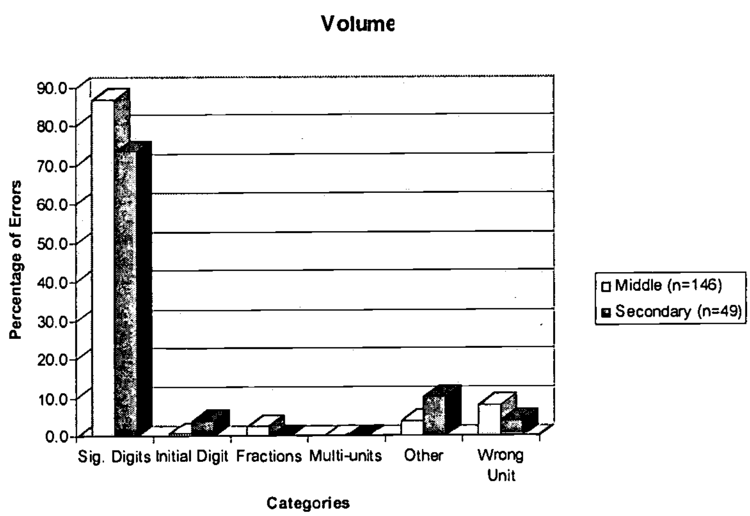

Table 3
Percentage of Misconceptions for Volume Measurement Task

		Misconception Categories					
Group	n	Sig. digits	Initial digits	Fractions	Multi-units	Other	Wrong unit
Middle	146	86.9	0.7	2.7	0.0	4.1	8.2
Secondary	49	73.5	4.1	0.0	0.0	10.2	4.1
Mid. + Sec.	195	83.6	1.5	2.1	0.0	5.6	7.2

Note. The values represent percentages of responses due to a particular type of misconception.

For mass, 65.1% of the teachers recorded the number of significant digits incorrectly. The percentage of teachers who used the incorrect standard measuring unit in their responses was 16.9% (see Figure 4 & Table 4). The two groups also displayed similar results in using the incorrect measuring unit in their responses as 16.3% of the secondary school teachers and 17.1% of the middle school teachers recorded the inappropriate unit. Data from the mass measurement task indicated that 3.6% of the teachers recorded measurements in fractions. Only 0.5% of them had misconceptions classified as missed initial digits, and 1.0% were in the multi-unit category. On the other hand, 21.5% of the teachers recorded measurements that were recorded in the "other" category.

Figure 4. Percentage of misconceptions for the mass measurement task for middle and secondary teachers.

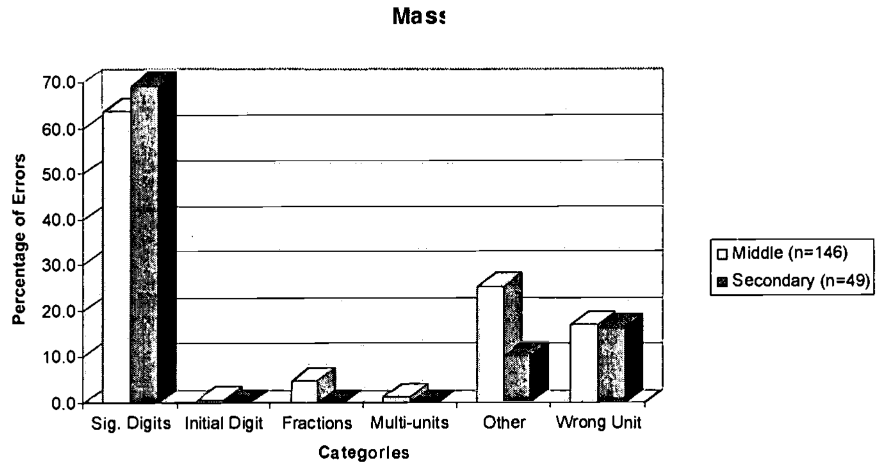

Table 4
Percentage of Misconceptions for Mass Measurement Task

		Misconception Categories					
Group	n	Sig. digits	Initial digits	Fractions	Multi-units	Other	Wrong unit
Middle	146	63.7	0.7	4.8	1.4	25.3	17.1
Secondary	49	69.4	0.0	0.0	0.0	10.2	16.3
Mid. + Sec.	195	65.1	0.5	3.6	1.0	21.5	16.9

Note. The values represent percentages of responses due to a particular type of misconception.

Significant Figures

The significant figure data for length, volume, and mass is further broken down in Figure 5 and Table 5. This figure illustrates that not only do most preservice teachers eliminate the final significant figure but many did not correctly measure the final two digits, especially for volume and mass. For middle school preservice teachers, 61.6% eliminated the final digit and 13.0%

missed the final two digits for length, 36.9% eliminated the final digit and 50.0% missed the final two digits for volume, while 29.5% eliminated the final digit and 34.2% missed the final two digits for mass. For secondary school preservice teachers, 67.4% eliminated the final digit for length while 6.1% missed the last two digits. For volume, 40.8% eliminated the final digit and 32.7% missed the last two. For the mass measurement task, 44.9% of the preservice teachers in the secondary school group eliminated the final digit, while 24.5% did not record correct responses for the final two digits. Accurately reading all of the significant digits was the most common misconception for both middle and secondary preservice teachers.

Figure 5. Percentages of significant figure responses for measurement tasks, for significant figures recorded correctly, with one figure missing, or two significant figures missing.

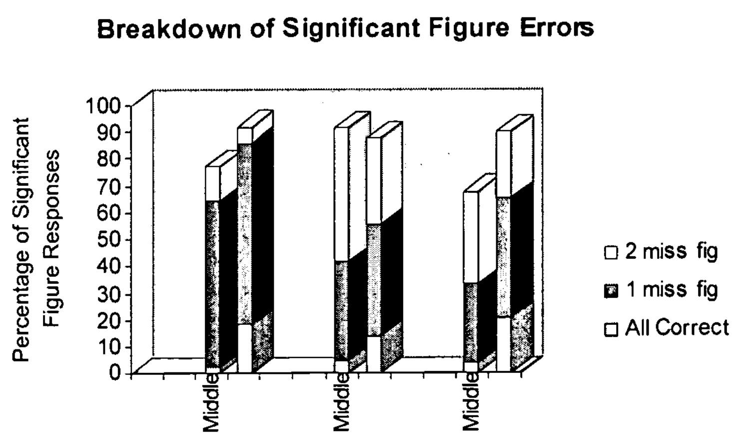

Table 5
Breakdown of Significant Figure Errors

		Significant figures (%)		
Tasks	Group	All correct	1 missing figure	2 missing figures
Length				
	Middle	2.7	61.6	13.0
	Secondary	18.4	67.4	6.1
Volume				
	Middle	4.8	36.9	50.0
	Secondary	14.3	40.8	32.7
Mass				
	Middle	4.1	29.5	34.2
	Secondary	20.4	44.9	24.5

Standard Units of Measurement

When analyzing the data regarding units of measurement, we found that the misconceptions included responses in which an incorrect unit was recorded (e.g., a response of 19.75 mm when the correct answer should have been recorded in centimeters [cm]), responses in which the standard unit of measurement was not correctly abbreviated (e.g., a response of 89.37 gms. when the correct abbreviation should have been recorded as "g"), and responses in which the unit of measurement was completely omitted.

For the length measurement task, 28.8% of the middle school teachers recorded an incorrect unit of measurement (see Table 6). This was, by far, the greatest percentage of misconception for units of measurement for both groups. Only 6.1% of the secondary school teachers had misconceptions in this category. Also for the length measurement task, 1.4% of the middle school teachers incorrectly in abbreviated the unit, and 2.7% did not record units for their

measurements. As for the secondary teachers, none of them (0%) had any misconceptions in abbreviating the unit for length. However, 2.0% omitted the unit from their measurement responses.

Table 6
Percentage of Errors for the Standard Units of Measurement

		Measurement task		
Error type	Group	Length	Volume	Mass
Incorrect unit				
	Middle	28.8	2.7	5.5
	Secondary	6.1	0	0
Abbreviation				
	Middle	1.4	0	2.1
	Secondary	0	0	6.1
Missing unit				
	Middle	2.7	2.7	3.4
	Secondary	2.0	4.1	10.2

For the volume measurement task, 2.7% of the middle school teachers responded with incorrect units of measurements. None (0%) of the secondary teachers had incorrect responses in this category. Neither group appeared to have any problems with abbreviating the unit for volume as none of them (0%) recorded incorrect abbreviations for this measurement task. As the data was analyzed for missing or omitted units for volume, we found that 2.7% of the middle school teachers omitted the units from their responses while 4.1% of the secondary school teachers failed to record any units for the measurement task.

For mass, the data revealed that 5.5% of the middle school teachers recorded incorrect units in their responses, 2.1% abbreviated their units incorrectly, and 3.4% omitted units from their responses. Data for the secondary school teachers revealed that none of them (0%) responded with an incorrect unit. However, 6.1% of them did not abbreviate their units correctly, and 10.2% of them did not record a unit with their responses. The latter percentage was the most common unit of measurement error for the secondary school teachers among all three measurement tasks.

Missing Initial Digit

The misconception that we had not anticipated was the missing initial digit. It became apparent when analyzing the measuring devices that devices such as meter sticks often label in increments of one through nine between larger increments of 10, 20, 30, and so on. For people who have not yet internalized how big a quantity is, the large unit is overlooked leading to measurements such as 8 instead of 28. For preservice teachers the data revealed initial digit misconceptions for length of 8.7%, for volume of 1.5%, and for mass of 0.5%.

Preservice Teachers' Reaction

After the preservice teachers performed the measurement tasks and turned in their responses, they got to see the class results. They were surprised to find that most of them did not know how to measure accurately. The instructor led a discussion about the performance assessment activity and pointed out common misconceptions that occur. Many of the preservice teachers, particularly the middle school teachers, expressed that they could not remember being taught how to make accurate measurements. They had always just assumed that they know how to make measurements accurately.

In the secondary class, the discussion also suggested that the special education science teachers had greater difficulty in making measurements. Since the data was collected anonymously within each class, this can not be proved. However, since these teachers tend to have less science background, it would seem likely that they would have greater difficulty.

Youden (1984) stated that "when making scientific measurements, it is standard practice to estimate positions in steps of one tenth of the interval." He went on to state that "in scientific work the knack of estimating tenths of a division on scales and instrument dials becomes almost automatic. The way to acquire this ability is to get some practice" (Youden, 1984).

After the common misconceptions were brought to the preservice teachers' attention, they displayed no problems in making the necessary adjustments to minimize errors. The only innovation used in teaching how to measure was a transparency of a meter stick which when projected on a screen allowed the teachers to physically see how the measurements were determined. The size of most instruments makes it difficult to directly observe what is being discussed in a measurement discussion. Turning the meter stick transparency 90° and drawing a few lines to make it a graduated cylinder, brings home the point that all analog measuring devices are read using the same procedure. In general, the teachers seemed pleased to know that there is a procedure to determine how many numbers can be read from a particular measuring instrument.

Conclusions and Recommendations

The preservice teachers in this study have great difficulty in accurately performing measurement tasks. Since over 75% of the preservice teachers in this study had received their bachelor's degree from institutions of higher education from across the U.S., this study suggests

that this is not a local problem but a national problem. Perhaps one of the reasons why U.S. students fair so poorly in measurement skills may be that many U.S. teachers do not fully understand the complete process of making accurate measurements.

According to the Third International Mathematics and Science Study (1996, 1997, 1998), U.S. fourth graders faired much better than eighth graders who in turn scored better than twelfth graders in the mathematics and science comparison. In mathematics content areas, our fourth graders exceeded the international average in five of the six areas assessed. They only scored below the international average in the one content area that assessed measurement skills (U.S. Department of Education, 1997). In eighth grade, scores dropped in both mathematics and science with U.S. students scoring below average in mathematics and slightly above average in science. For the six mathematics subject areas assessed, measurement was again the area of poorest performance for U.S. students. At twelfth grade measurement scores were not reported (U.S. Department of Education, 1998).

The most common measurement misconceptions made by the preservice teachers in this study was reading all of the digits accurately, especially the final estimated digit. The teachers tended to read fewer digits than what could actually be read by the instrument. The second most common error was recording the correct unit of measurement using standard abbreviations. Other misconceptions were recording metric measurements using fractions, omitting initial digits, and combining multiple units. When the teachers became aware of the common measurement misconceptions and that there was an actual process to make accurate measurements, they quickly learned how. Therefore, awareness seems to be the greatest issue.

The need to teach accurate measurement skills in the elementary, middle, and secondary school classrooms has been identified in the *NCTM Standards* (1989) and the *National Science*

Education Standards (1996). In order for this to occur, it is vital that teachers understand the measurement process in order to teach these skills to children. If teachers know how to use standard measuring devices to make accurate measurements and understand the common misconceptions, then they will be better able to teach children how to measure accurately. With practice, accurate measurement will become an automatic skill. This may not eliminate the deficit shown in our performance in assessments such as the TIMSS, but it will get us started in the right direction and maybe back up to standard.

References

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. Oxford University Press, Inc.: New York.

Gabel, D. L. (1993) *Introductory Science Skills*. Waveland Press: Prospect Heights, IL.

Geddes, D. *et. al.* (1994) *Measurement in the Middle Grades: Addenda Series, Grades 5-8*. National Council of Teachers of Mathematics: Reston, VA.

Haber-Schaim, U., Abegg, G. L., Dodge, J. H., Kirksey, H. G., and Walter, J. A. (1987). *Introductory Physical Science*. Prentice-Hall: Englewood Cliffs, NJ.

Hiebert, J. (1984, March). Why so some children have trouble learning measurement concepts? *Arithmetic Teacher*. 32 , 19-24.

Jones, L. R., Mullis, I. V., Raizen, S. A., Weiss, I. R., and Weston, E. A. (1992). *The 1990 Science Report Card*. National Center for Educational Statistics, U.S. Department of Education: Washington, DC.

Mullen, G. S. (1985). How do you measure up? *Arithmetic Teacher*. 33 (2), 16-21.

Mullis, I. V., and Jenkins, L. B. (1988). *The Science Report Card: Elements of Risk and Recovery*. National Assessment of Educational Progress, Educational Testing Service: Princeton, NJ.

National Council of Teachers of Mathematics. (1989) *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA.

National Research Council. (1996). *National Science Education Standards*. National Academy Press: Washington, DC.

Nelson, J. H. and Kemp, K. C. (1977). *Laboratory Experiments for Brown and LeMay, Chemistry, The Central Science*. Prentice-Hall: Englewood Cliffs, NJ.

O'Sullivan, C. Y., Reese, C. M., and Mazzeo, J. (1997). *NAEP 1996 Science Report Card for the Nation and the States*. (NCES 97-497). National Center for Education Statistics: Washington, DC.

Reese, C. M., Miller, K. E., Mazzeo, J., and Dossey, J. A. (1997). *NAEP 1996 Mathematics Report Card for the Nation and the States*. (NCES 97-488). National Center for Education Statistics: Washington, DC.

Sterling, D. R. (1998, February). Getting Students to Measure Up. *Science Scope. 21*(5), 14-17.

Sterling, D. R. (1999, January). Measuring Skills. *The Science Teacher. 66*(1), 58-62.

U.S. Department of Education. (1996). *Pursuing Excellence: A Study of U.S. Eighth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context.* (NCES 97-198). U.S. Government Printing Office: Washington, DC.

U.S. Department of Education. (1997). *Pursuing Excellence: A Study of U.S. Fourth-Grade Mathematics and Science Achievement in International Context*. (NCES 97-255). U.S. Government Printing Office: Washington, DC.

U.S. Department of Education. (1998). *Pursuing Excellence: A Study of U.S. Twelfth-Grade Mathematics and Science Achievement in International Context*. (NCES 98-049). U.S. Government Printing Office: Washington, DC.

Youden, W. J. (1984). *Experimentation and Measurement*. U.S. Government Printing Office: Washington, DC.

Youden, W. J. (1985). *Experimentation and Measurement*. National Science Teachers Association: Washington, DC.

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